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Restoration approach in WDM optical networks

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Abstract

Critical applications require proactive-based survivability strategy which provides 100% degree of survivability, low blocking probability and very low restoration time. In this paper, we have proposed an efficient proactive restoration approach for WDM optical network that efficiently utilizes the resources and reduces blocking probability as compared to existing proactive restoration approach. It gives priority to primary lightpath as compared to backup lightpath because primary lightpath should not share resources with other lightpaths in critical applications but backup lightpaths can share the resources, i.e. backup multiplexing.

Keywords: WDM; Restoration; Backup multiplexing; Blocking probability

1. Introduction

With the growth of communication technology at high speed, WDM optical networks are the future network, because these type of networks offers many advantages and can handle large amount of data for communication. WDM is the most important technique that allows for expanding the inherent great capacity of optical fibers. It modulates multiple information signals (optical signals) at different wavelengths, the resulting signals are combined and transmitted simultaneously over the same optical fiber. It establishes communication between pairs of network nodes by establishing transmitter–receiver paths and assigning wavelength to each path so that no two paths going through the same fiber link use the same wavelength. By using this technique optical networks make use of the enormous bandwidth of an optical fiber.

Restoration in optical networks refers to the process of rerouting the affected traffic after component failure. Lightpath is a connection in all optical networks, which is totally optical except at the end nodes. There are two types of lightpaths: primary lightpath and backup lightpath. Primary lightpaths are those lightpaths upon which data transmission takes place under normal conditions. Backup lightpaths are those lightpaths which carries the data when primary lightpath cannot be used due to failure occurrence. Backup multiplexing is the technique in which backup lightpaths can share the resources. Survivability features must be provided in optical networks in order to achieve the advantages of high speed and high network connectivity. In case of a failure, a tremendous amount of information can be lost, affecting a huge number of requests. In this scenario, network survivability becomes an important issue. The restoration control strategy can be either centralized or distributed. In centralized control, there is a central controller to keep track of the state of the network. It is also responsible for selecting the path for

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data transmission. Most of the work done in this field is based on centralized control. For large networks, distributed control is preferred over centralized control because of low control overhead. Distributed control strategy requires exchange of control messages among nodes. The distributed control generally results in the possibility of resource reservation conflicts among simultaneous path establishments and poor resource utilization.

In this paper, we have proposed a restoration approach. Proposed strategy can be used for critical applications as it provides 100% degree of survivability and very low restoration time as backup lightpath is established in advance. Although it reserves the resources in advance, the resources are utilized very efficiently because of the backup multiplexing technique. This paper is organized as follows. Section 2 introduces the restoration in WDM networks networks. Section 3 explains the existing and proposed restoration approaches. Section 4 will focus on performance evaluation of proposed strategy. Conclusions are drawn in section 5.

2. Restoration in WDM networks

Restoration is the process of reconfiguration and reestablishment of connection upon failure of links, fibers, nodes, wavelength channels and/or switches. Provisioning and restoration are very important issues in WDM optical networks. Provisioning is important due to the factor that deals with resource allocation but the aim should be that the resource requirement is as minimum as possible. Restoration is greatly effected by the provisioning which deals with resource allocation. Depending upon the time of resource allocation for backup lightpath, the restoration can be categorized as proactive and reactive techniques. Proactive techniques are those techniques in which the resources are reserved in advance, when the connection request arrives. These techniques are very fast and result in high degree of survivability. Due to high degree of survivability, these techniques are to be used for reliable systems. Reactive techniques are those techniques in which backup lightpath is searched after the occurrence of failure. The restoration techniques can be categorized in various ways. They can be categorized as link-based and path-based [1]. In link-based restoration, a new path is selected between end nodes of failed link only. In path-based restoration, a new path is searched between the source and the destination. The path-based restoration can be further categorized as failure dependent and failure independent. In failure dependent method, associated with each failure, a backup lightpath is there. The backup lightpath need not be link and node disjoint with the primary lightpath. In failure independent approach, there is only one backup lightpath. In it, both lightpaths need to be link and node disjoint. Resources for backup lightpath can be reserved in three ways: primary backup multiplexing, dedicated backup lightpath and backup multiplexing. In primary backup multiplexing technique, a primary lightpath and one or more backup lightpath can share the resources [2], in dedicated backup lightpath, there is one dedicated backup lightpath, i.e. the resources allocated to backup lightpath are not shareable. But in backup multiplexing, the resources allocated to one backup lightpath can be shared by other backup lightpaths. Many terms are associated with restoration such as degree of survivability, resource utilization and restoration time [3,4,5]. Degree of survivability is the ratio of traffic affected that has been restored by the amount of the total traffic affected. Restoration time is the time taken by the system for restoration after failure.

3. Restoration approaches

The restoration approaches work in the proactive manner and are based on the concept of path-based, failure-independent restoration and single failure model. These can work for both node and link failure. Backup multiplexing technique for resource reservation has been used to efficiently utilize the resources and to reduce the blocking probability. If backup multiplexing is not employed, then the resources required are at least double the resources required in networks with fault tolerance capability because usually the backup lightpath is longer than its corresponding primary lightpaths. The lightpaths established will be wavelength continuous. These give 100% degree of survivability for all the connection requests accepted. The proposed approach result in more connections as compared to existing approach thus reduces the blocking probability.

3.1. Existing approach (individual connection approach)

In this approach, each connection request is taken one by one from all the connection requests. Backup lightpath for each connection is established immediately after the establishment of the primary lightpath. Then another s–d pair for connection establishment from the list is considered. It gives priority to the connections according to their position in the list. There are no chances that a connection request earlier in the list will be accommodated after a connection request later in the list. (P1, B1), (P2, B2), …, (Pn, Bn) is the sequence in which the lightpath establishment is tried in existing approach if there are n s–d pairs for connection

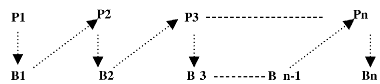

Fig. 1. Sequence of lightpath establishment (individual connection approach).

establishment as shown in Fig. 1. Here P1 is primary lightpath for first s–d pair, P2 is the primary lightpath for second s–d pair and so on and B1 is backup lightpath for first s–d pair, B2 is the backup lightpath for second s–d pair and so on.

3.2. Proposed approach (group connection approach)

For given set of connection requests, first of all establish the primary lightpath for each connection request in the set, if possible. Then the backup lightpaths corresponding to these primary lightpaths are established from the remaining resources. It gives priority to primary lightpath as compared to backup lightpath. If either the primary or backup lightpath cannot be established for any connection request, then that connection request is dropped so as to provide 100% degree of survivability for all the connections accepted which is required for all the critical applications. (P1, P2, …, Pn), (B1, B2, …, Bn) is the sequence in which the lightpaths are tried in proposed approach if there are n s–d pairs for connection establishment as shown in Fig. 2.

There are two types of lightpaths to be established: (1) primary lightpath and (2) backup lightpath. The priority of lightpath establishment should be given to primary lightpath as compared to backup lightpath, because of following reasons:

(1) There is no sharing of resources of primary lightpath with any other primary lightpath. Backup lightpaths can share the resources by backup multiplexing. So priority is given to primary lightpaths than backup lightpaths.
(2) The traffic most of the time is carried by primary lightpaths and backup lightpaths are only used in the case of any failure.
(3) All the primary lightpaths are used for data transmission but this is not the case for backup lightpaths. Only some of the backup lightpaths are used in the case of failure and if the failure does not occur then no backup lightpath is used.
(4) Backup lightpaths are mostly longer than their corresponding primary lightpaths and it requires more channels and if established earlier adversely affects the network performance in terms of resources utilization. So the priority is given to primary lightpaths.

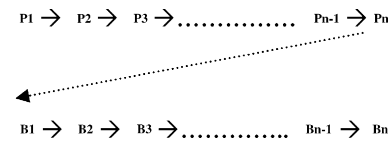

Fig. 2. Sequence of lightpath establishment (group connection approach).

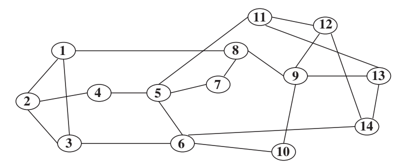

Fig. 3. NSFNET network model.

So backup lightpaths are established with the remaining resources after establishing primary lightpaths. It gives fantastic results because primary lightpaths can be established earlier when many resources are available (those would otherwise have been occupied by backup lightpaths). Hence the proposed approach efficiently utilizes the resources along with reducing the blocking probability.

4. Performance evaluation

The network shown in Fig. 3 is taken as the example network. In this, single failure model has been assumed. The survivability strategy is proactive, path based, failure independent, backup multiplexing and for static traffic. Two wavelengths per fiber have been considered and the following source destination (s–d) pairs for connection establishment have been taken (1–4), (2–10), (7–9), (1–3), (9–14), (9–13), (11–9), (4–6) and (5–13).

Tables 1 and 2 gives the overview of connection requests for all s–d pairs for individual connection approach and group connection approach, respectively. There is one row corresponding to each s–d pair. First column indicates the s–d pair, second column shows the primary route based on shortest path algorithm and the next column gives the wavelength for primary lightpath establishment. Fourth column shows the backup route. It is chosen with the help of alternate shortest path algorithm and it is link and node disjoint with primary route. The last column shows the wavelength on backup route for the given s–d pair.

The dashed lines in third column represents that none of the wavelengths was available for primary lightpath establishment. The dashed lines in fourth and fifth column shows that the backup lightpath is not established either due to the unavailability of primary lightpath or free channels for backup lightpath. The unavailability of primary lightpath is shown by the

Table 1. Overview of connection requests for individual connection approach

s–d pairs	Primary route	Wavelength for primary route	Backup route	Wavelength for backup route
1–4	1–2–4	1	1–8–7–5–4	1
2–10	2–3–6–10	1	2–1–8–9–10	2
7–9	7–8–9	–	–	–
1–3	1–3	1	1–2–3	2
9–14	9–13–14	1	9–12–14	1
9–13	9–13	2	9–12–14–13	2
6–13	6–14–13	–	–	–
11–9	11–12–9	–	–	–
4–6	4–5–6	2	4–2–3–6	2
5–13	5–11–13	1	–	–

Table 2. Overview of connection requests for group connection approach

s–d pairs	Primary route	Wavelength for primary route	Backup route	Wavelength for backup route
1–4	1–2–4	1	1–8–7–5–4	2
2–10	2–3–6–10	1	2–1–8–9–10	2
7–9	7–8–9	1	7–5–11–13–9	2
1–3	1–3	1	1–2–3	2
9–14	9–13–14	1	9–12–14	2
9–13	9–13	2	9–12–14–13	2
6–13	6–14–13	2	6–10–9–13	2
11–9	11–12–9	1	11–13–9	2
4–6	4–5–6	1	4–2–3–6	2
5–13	5–11–13	1	5–6–14–13	2

dashed lines in the third column of the corresponding row.

Shortest path algorithm is used to find a route based on the hop count because it results in the selection of a route that uses minimum number of links. As less number of links are used, it leads to better utilization of resources and reduces blocking probability. The use of longer route will adversely affect the acceptance of another connection requests increasing blocking probability and increased connection establishment time for accepted connections, which is undesirable. The connection requests for s–d pairs: (1–3), (6–7), (8–10), (9–13), (11–13) and (6–14) have been accepted just due to backup multiplexing and thus leads to reduced blocking probability (Fig. 4).

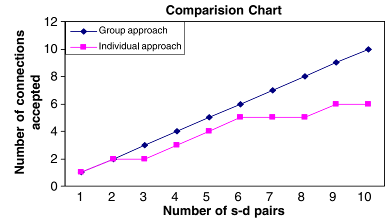

Fig. 4. Comparison chart.

5. Conclusions

The restoration control strategy can be either centralized or distributed. In centralized control, there is a central controller to keep track of the state of the network. It is also responsible for selecting the path for data transmission. Most of the work done in survivability field is based on centralized control. For large and scalable networks, distributed control is preferred over centralized control because of low control overhead. Distributed control strategy requires exchange of control messages among nodes. The distributed control generally results in the possibility of poor resource utilization of resources and reservation conflicts among simultaneous path establishments. The proposed strategy results in an efficient utilization of resources as backup multiplexing technique is used thus avoiding the problem of poor resource utilization. The second problem has been resolved in it by reserving the resources by making entry in the link information table. The proposed strategy also makes the system reliable as it gives 100% degree of survivability for all the connections accepted. So it can be used for large and/or scalable networks for handling critical data.

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